

Search for sneutrino particles in $e + \mu$ final states in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV

V.M. Abazov³⁶, B. Abbott⁷⁶, M. Abolins⁶⁶, B.S. Acharya²⁹, M. Adams⁵², T. Adams⁵⁰, E. Aguilo⁶, S.H. Ahn³¹, M. Ahsan⁶⁰, G.D. Alexeev³⁶, G. Alkhazov⁴⁰, A. Alton^{65,a}, G. Alverson⁶⁴, G.A. Alves², M. Anastasoie³⁵, L.S. Ancu³⁵, T. Andeen⁵⁴, S. Anderson⁴⁶, B. Andrieu¹⁷, M.S. Anzelc⁵⁴, Y. Arnoud¹⁴, M. Arov⁶¹, M. Arthaud¹⁸, A. Askew⁵⁰, B. Åsman⁴¹, A.C.S. Assis Jesus³, O. Atramentov⁵⁰, C. Autermann²¹, C. Avila⁸, C. Ay²⁴, F. Badaud¹³, A. Baden⁶², L. Bagby⁵³, B. Baldin⁵¹, D.V. Bandurin⁶⁰, S. Banerjee²⁹, P. Banerjee²⁹, E. Barberis⁶⁴, A.-F. Barfuss¹⁵, P. Bargassa⁸¹, P. Baringer⁵⁹, J. Barreto², J.F. Bartlett⁵¹, U. Bassler¹⁸, D. Bauer⁴⁴, S. Beale⁶, A. Bean⁵⁹, M. Begalli³, M. Begel⁷², C. Belanger-Champagne⁴¹, L. Bellantoni⁵¹, A. Bellavance⁵¹, J.A. Benitez⁶⁶, S.B. Beri²⁷, G. Bernardi¹⁷, R. Bernhard²³, I. Bertram⁴³, M. Besançon¹⁸, R. Beuselinck⁴⁴, V.A. Bezzubov³⁹, P.C. Bhat⁵¹, V. Bhatnagar²⁷, C. Biscarat²⁰, G. Blazey⁵³, F. Blekman⁴⁴, S. Blessing⁵⁰, D. Bloch¹⁹, K. Bloom⁶⁸, A. Boehnlein⁵¹, D. Boline⁶³, T.A. Bolton⁶⁰, G. Borissov⁴³, T. Bose⁷⁸, A. Brandt⁷⁹, R. Brock⁶⁶, G. Brooijmans⁷¹, A. Bross⁵¹, D. Brown⁸², X.B. Bu⁷, N.J. Buchanan⁵⁰, D. Buchholz⁵⁴, M. Buehler⁸², V. Buescher²², V. Bunichev³⁸, S. Burdin^{43,b}, S. Burke⁴⁶, T.H. Burnett⁸³, C.P. Buszello⁴⁴, J.M. Butler⁶³, P. Calfayan²⁵, S. Calvet¹⁶, J. Cammin⁷², W. Carvalho³, B.C.K. Casey⁵¹, N.M. Cason⁵⁶, H. Castilla-Valdez³³, S. Chakrabarti¹⁸, D. Chakraborty⁵³, K.M. Chan⁵⁶, K. Chan⁶, A. Chandra⁴⁹, F. Charles^{19,†}, E. Cheu⁴⁶, F. Chevallier¹⁴, D.K. Cho⁶³, S. Choi³², B. Choudhary²⁸, L. Christofek⁷⁸, T. Christoudias⁴⁴, S. Cihangir⁵¹, D. Claes⁶⁸, Y. Coadou⁶, M. Cooke⁸¹, W.E. Cooper⁵¹, M. Corcoran⁸¹, F. Couderc¹⁸, M.-C. Cousinou¹⁵, S. Crépe-Renaudin¹⁴, D. Cutts⁷⁸, M. Ćwiok³⁰, H. da Motta², A. Das⁴⁶, G. Davies⁴⁴, K. De⁷⁹, S.J. de Jong³⁵, E. De La Cruz-Burelo⁶⁵, C. De Oliveira Martins³, J.D. Degenhardt⁶⁵, F. Déliot¹⁸, M. Demarteau⁵¹, R. Demina⁷², D. Denisov⁵¹, S.P. Denisov³⁹, S. Desai⁵¹, H.T. Diehl⁵¹, M. Diesburg⁵¹, A. Dominguez⁶⁸, H. Dong⁷³, L.V. Dudko³⁸, L. Duflot¹⁶, S.R. Dugad²⁹, D. Duggan⁵⁰, A. Duperrin¹⁵, J. Dyer⁶⁶, A. Dyshkant⁵³, M. Eads⁶⁸, D. Edmunds⁶⁶, J. Ellison⁴⁹, V.D. Elvira⁵¹, Y. Enari⁷⁸, S. Eno⁶², P. Ermolov³⁸, H. Evans⁵⁵, A. Evdokimov⁷⁴, V.N. Evdokimov³⁹, A.V. Ferapontov⁶⁰, T. Ferbel⁷², F. Fiedler²⁴, F. Filthaut³⁵, W. Fisher⁵¹, H.E. Fisk⁵¹, M. Ford⁴⁵, M. Fortner⁵³, H. Fox²³, S. Fu⁵¹, S. Fuess⁵¹, T. Gadfort⁸³, C.F. Galea³⁵, E. Gallas⁵¹, E. Galyaev⁵⁶, C. Garcia⁷², A. Garcia-Bellido⁸³, V. Gavrilov³⁷, P. Gay¹³, W. Geist¹⁹, D. Gelé¹⁹, C.E. Gerber⁵², Y. Gershtein⁵⁰, D. Gillberg⁶, G. Ginther⁷², N. Gollub⁴¹, B. Gómez⁸, A. Goussiou⁵⁶, P.D. Grannis⁷³, H. Greenlee⁵¹, Z.D. Greenwood⁶¹, E.M. Gregores⁴, G. Grenier²⁰, Ph. Gris¹³, J.-F. Grivaz¹⁶, A. Grohsjean²⁵, S. Grünendahl⁵¹, M.W. Grünewald³⁰, J. Guo⁷³, F. Guo⁷³, P. Gutierrez⁷⁶, G. Gutierrez⁵¹, A. Haas⁷¹, N.J. Hadley⁶², P. Haefner²⁵, S. Hagopian⁵⁰, J. Haley⁶⁹, I. Hall⁶⁶, R.E. Hall⁴⁸, L. Han⁷, K. Hanagaki⁵¹, P. Hansson⁴¹, K. Harder⁴⁵, A. Harel⁷², R. Harrington⁶⁴, J.M. Hauptman⁵⁸, R. Hauser⁶⁶, J. Hays⁴⁴, T. Hebbeker²¹, D. Hedin⁵³, J.G. Hegeman³⁴, J.M. Heinmiller⁵², A.P. Heinson⁴⁹, U. Heintz⁶³, C. Hensel⁵⁹, K. Herner⁷³, G. Hesketh⁶⁴, M.D. Hildreth⁵⁶, R. Hirosky⁸², J.D. Hobbs⁷³, B. Hoeneisen¹², H. Hoeth²⁶, M. Hohlfield²², S.J. Hong³¹, S. Hossain⁷⁶, P. Houben³⁴, Y. Hu⁷³, Z. Hubacek¹⁰, V. Hynek⁹, I. Iashvili⁷⁰, R. Illingworth⁵¹, A.S. Ito⁵¹, S. Jabeen⁶³, M. Jaffré¹⁶, S. Jain⁷⁶, K. Jakobs²³, C. Jarvis⁶², R. Jesik⁴⁴, K. Johns⁴⁶, C. Johnson⁷¹, M. Johnson⁵¹, A. Jonckheere⁵¹, P. Jonsson⁴⁴, A. Juste⁵¹, D. Käfer²¹, E. Kajfasz¹⁵, A.M. Kalinin³⁶, J.R. Kalk⁶⁶, J.M. Kalk⁶¹, S. Kappler²¹, D. Karmanov³⁸, P. Kasper⁵¹, I. Katsanos⁷¹, D. Kau⁵⁰, R. Kaur²⁷, V. Kaushik⁷⁹, R. Kehoe⁸⁰, S. Kermiche¹⁵, N. Khalatyan⁵¹, A. Khanov⁷⁷, A. Kharchilava⁷⁰, Y.M. Kharzheev³⁶, D. Khatidze⁷¹, H. Kim³², T.J. Kim³¹, M.H. Kirby⁵⁴, M. Kirsch²¹, B. Klima⁵¹, J.M. Kohli²⁷, J.-P. Konrath²³, M. Kopal⁷⁶, V.M. Korabely³⁹, A.V. Kozelov³⁹, D. Krop⁵⁵, T. Kuhl²⁴, A. Kumar⁷⁰, S. Kunori⁶², A. Kupco¹¹, T. Kurča²⁰, J. Kvita⁹, F. Lacroix¹³, D. Lam⁵⁶, S. Lammers⁷¹, G. Landsberg⁷⁸, P. Lebrun²⁰, W.M. Lee⁵¹, A. Leflat³⁸, F. Lehner⁴², J. Lellouch¹⁷, J. Leveque⁴⁶, P. Lewis⁴⁴, J. Li⁷⁹, Q.Z. Li⁵¹, L. Li⁴⁹, S.M. Lietti⁵, J.G.R. Lima⁵³, D. Lincoln⁵¹, J. Linnemann⁶⁶, V.V. Lipaev³⁹, R. Lipton⁵¹, Y. Liu⁷, Z. Liu⁶, L. Lobo⁴⁴, A. Lobodenko⁴⁰, M. Lokajicek¹¹, P. Love⁴³, H.J. Lubatti⁸³, A.L. Lyon⁵¹, A.K.A. Maciel², D. Mackin⁸¹, R.J. Madaras⁴⁷, P. Mättig²⁶, C. Magass²¹, A. Magerkurth⁶⁵, P.K. Mal⁵⁶, H.B. Malbouisson³, S. Malik⁶⁸, V.L. Malyshev³⁶, H.S. Mao⁵¹, Y. Maravin⁶⁰, B. Martin¹⁴, R. McCarthy⁷³, A. Melnitchouk⁶⁷, A. Mendes¹⁵, L. Mendoza⁸, P.G. Mercadante⁵, M. Merkin³⁸, K.W. Merritt⁵¹, J. Meyer^{22,d}, A. Meyer²¹, T. Millet²⁰, J. Mitrevski⁷¹, J. Molina³, R.K. Mommsen⁴⁵, N.K. Mondal²⁹, R.W. Moore⁶, T. Moulik⁵⁹, G.S. Muanza²⁰, M. Mulders⁵¹, M. Mulhearn⁷¹, O. Mundal²², L. Mundim³, E. Nagy¹⁵, M. Naimuddin⁵¹, M. Narain⁷⁸, N.A. Naumann³⁵, H.A. Neal⁶⁵, J.P. Negret⁸, P. Neustroev⁴⁰, H. Nilsen²³, H. Nogima³, A. Nomerotski⁵¹, S.F. Novaes⁵, T. Nunnemann²⁵, V. O'Dell⁵¹, D.C. O'Neil¹⁶, G. Obrant⁴⁰, C. Ochando¹⁶, D. Onoprienko⁶⁰, N. Oshima⁵¹, J. Osta⁵⁶, R. Otec¹⁰, G.J. Otero y Garzón⁵¹, M. Owen⁴⁵, P. Padley⁸¹, M. Pangilinan⁷⁸, N. Parashar⁵⁷, S.-J. Park⁷², S.K. Park³¹, J. Parsons⁷¹, R. Partridge⁷⁸, N. Parua⁵⁵, A. Patwa⁷⁴, G. Pawloski⁸¹, B. Penning²³, M. Perfilov³⁸, K. Peters⁴⁵, Y. Peters²⁶, P. Pétrouff¹⁶, M. Petteni⁴⁴,

R. Piegai¹, J. Piper⁶⁶, M.-A. Pleier²², P.L.M. Podesta-Lerma^{33,c}, V.M. Podstavkov⁵¹, Y. Pogorelov⁵⁶,
M.-E. Pol², P. Polozov³⁷, B.G. Pope⁶⁶, A.V. Popov³⁹, C. Potter⁶, W.L. Prado da Silva³, H.B. Prosper⁵⁰,
S. Protopopescu⁷⁴, J. Qian⁶⁵, A. Quadt^{22,d}, B. Quinn⁶⁷, A. Rakitine⁴³, M.S. Rangel², K. Ranjan²⁸, P.N. Ratoff⁴³,
P. Renkel⁸⁰, S. Reucroft⁶⁴, P. Rich⁴⁵, M. Rijssenbeek⁷³, I. Ripp-Baudot¹⁹, F. Rizatdinova⁷⁷, S. Robinson⁴⁴,
R.F. Rodrigues³, M. Rominsky⁷⁶, C. Royon¹⁸, P. Rubinov⁵¹, R. Ruchti⁵⁶, G. Safronov³⁷, G. Sajot¹⁴,
A. Sánchez-Hernández³³, M.P. Sanders¹⁷, A. Santoro³, G. Savage⁵¹, L. Sawyer⁶¹, T. Scanlon⁴⁴, D. Schaile²⁵,
R.D. Schamberger⁷³, Y. Scheglov⁴⁰, H. Schellman⁵⁴, P. Schieferdecker²⁵, T. Schliephake²⁶, C. Schwanenberger⁴⁵,
A. Schwartzman⁶⁹, R. Schwienhorst⁶⁶, J. Sekaric⁵⁰, H. Severini⁷⁶, E. Shabalina⁵², M. Shamim⁶⁰, V. Shary¹⁸,
A.A. Shchukin³⁹, R.K. Shivpuri²⁸, V. Siccaldi¹⁹, V. Simak¹⁰, V. Sirotenko⁵¹, P. Skubic⁷⁶, P. Slattery⁷²,
D. Smirnov⁵⁶, J. Snow⁷⁵, G.R. Snow⁶⁸, S. Snyder⁷⁴, S. Söldner-Rembold⁴⁵, L. Sonnenschein¹⁷, A. Sopczak⁴³,
M. Sosebee⁷⁹, K. Soustruznik⁹, M. Souza², B. Spurlock⁷⁹, J. Stark¹⁴, J. Steele⁶¹, V. Stolin³⁷, D.A. Stoyanova³⁹,
J. Strandberg⁶⁵, S. Strandberg⁴¹, M.A. Strang⁷⁰, M. Strauss⁷⁶, E. Strauss⁷³, R. Ströhmer²⁵, D. Strom⁵⁴,
L. Stutte⁵¹, S. Sumowidagdo⁵⁰, P. Svoisky⁵⁶, A. Sznajder³, M. Talby¹⁵, P. Tamburello⁴⁶, A. Tanasijczuk¹,
W. Taylor⁶, J. Temple⁴⁶, B. Tiller²⁵, F. Tissandier¹³, M. Titov¹⁸, V.V. Tokmenin³⁶, T. Toole⁶², I. Torchiani²³,
T. Trefzger²⁴, D. Tsybychev⁷³, B. Tuchming¹⁸, C. Tully⁶⁹, P.M. Tuts⁷¹, R. Unalan⁶⁶, S. Uvarov⁴⁰,
L. Uvarov⁴⁰, S. Uzunyan⁵³, B. Vachon⁶, P.J. van den Berg³⁴, R. Van Kooten⁵⁵, W.M. van Leeuwen³⁴,
N. Varelas⁵², E.W. Varnes⁴⁶, I.A. Vasilyev³⁹, M. Vaupel²⁶, P. Verdier²⁰, L.S. Vertogradov³⁶, M. Verzocchi⁵¹,
F. Villeneuve-Seguer⁴⁴, P. Vint⁴⁴, P. Vokac¹⁰, E. Von Toerne⁶⁰, M. Voutilainen^{68,e}, R. Wagner⁶⁹, H.D. Wahl⁵⁰,
L. Wang⁶², M.H.L.S Wang⁵¹, J. Warchol⁵⁶, G. Watts⁸³, M. Wayne⁵⁶, M. Weber⁵¹, G. Weber²⁴, A. Wenger^{23,f},
N. Wormes²², M. Wetstein⁶², A. White⁷⁹, D. Wicke²⁶, G.W. Wilson⁵⁹, S.J. Wimpenny⁴⁹, M. Wobisch⁶¹,
D.R. Wood⁶⁴, T.R. Wyatt⁴⁵, Y. Xie⁷⁸, S. Yacoub⁵⁴, R. Yamada⁵¹, M. Yan⁶², T. Yasuda⁵¹, Y.A. Yatsunenko³⁶,
H. Yin⁷, K. Yip⁷⁴, H.D. Yoo⁷⁸, S.W. Youn⁵⁴, J. Yu⁷⁹, A. Zatserklyaniy⁵³, C. Zeitnitz²⁶, T. Zhao⁸³, B. Zhou⁶⁵,
J. Zhu⁷³, M. Zielinski⁷², D. Zieminska⁵⁵, A. Zieminski^{55,†}, L. Zivkovic⁷¹, V. Zutshi⁵³, and E.G. Zverev³⁸

(The $D\bar{O}$ Collaboration)

¹Universidad de Buenos Aires, Buenos Aires, Argentina

²LAFEX, Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, Brazil

³Universidade do Estado do Rio de Janeiro, Rio de Janeiro, Brazil

⁴Universidade Federal do ABC, Santo André, Brazil

⁵Instituto de Física Teórica, Universidade Estadual Paulista, São Paulo, Brazil

⁶University of Alberta, Edmonton, Alberta, Canada,

Simon Fraser University, Burnaby, British Columbia,

Canada, York University, Toronto, Ontario, Canada,

and McGill University, Montreal, Quebec, Canada

⁷University of Science and Technology of China, Hefei, People's Republic of China

⁸Universidad de los Andes, Bogotá, Colombia

⁹Center for Particle Physics, Charles University, Prague, Czech Republic

¹⁰Czech Technical University, Prague, Czech Republic

¹¹Center for Particle Physics, Institute of Physics,
Academy of Sciences of the Czech Republic, Prague, Czech Republic

¹²Universidad San Francisco de Quito, Quito, Ecuador

¹³Laboratoire de Physique Corpusculaire, IN2P3-CNRS,
Université Blaise Pascal, Clermont-Ferrand, France

¹⁴Laboratoire de Physique Subatomique et de Cosmologie,
IN2P3-CNRS, Université de Grenoble 1, Grenoble, France

¹⁵CPPM, IN2P3-CNRS, Université de la Méditerranée, Marseille, France

¹⁶Laboratoire de l'Accélérateur Linéaire, IN2P3-CNRS et Université Paris-Sud, Orsay, France

¹⁷LPNHE, IN2P3-CNRS, Universités Paris VI and VII, Paris, France

¹⁸DAPNIA/Service de Physique des Particules, CEA, Saclay, France

¹⁹IPHC, Université Louis Pasteur et Université de Haute Alsace, CNRS, IN2P3, Strasbourg, France

²⁰IPNL, Université Lyon 1, CNRS/IN2P3, Villeurbanne, France and Université de Lyon, Lyon, France

²¹III. Physikalisches Institut A, RWTH Aachen, Aachen, Germany

²²Physikalisches Institut, Universität Bonn, Bonn, Germany

²³Physikalisches Institut, Universität Freiburg, Freiburg, Germany

²⁴Institut für Physik, Universität Mainz, Mainz, Germany

²⁵Ludwig-Maximilians-Universität München, München, Germany

²⁶Fachbereich Physik, University of Wuppertal, Wuppertal, Germany

²⁷Panjab University, Chandigarh, India

²⁸Delhi University, Delhi, India

- ²⁹Tata Institute of Fundamental Research, Mumbai, India
³⁰University College Dublin, Dublin, Ireland
³¹Korea Detector Laboratory, Korea University, Seoul, Korea
³²SungKyunKwan University, Suwon, Korea
³³CINVESTAV, Mexico City, Mexico
³⁴FOM-Institute NIKHEF and University of Amsterdam/NIKHEF, Amsterdam, The Netherlands
³⁵Radboud University Nijmegen/NIKHEF, Nijmegen, The Netherlands
³⁶Joint Institute for Nuclear Research, Dubna, Russia
³⁷Institute for Theoretical and Experimental Physics, Moscow, Russia
³⁸Moscow State University, Moscow, Russia
³⁹Institute for High Energy Physics, Protvino, Russia
⁴⁰Petersburg Nuclear Physics Institute, St. Petersburg, Russia
⁴¹Lund University, Lund, Sweden, Royal Institute of Technology and Stockholm University, Stockholm, Sweden, and Uppsala University, Uppsala, Sweden
⁴²Physik Institut der Universität Zürich, Zürich, Switzerland
⁴³Lancaster University, Lancaster, United Kingdom
⁴⁴Imperial College, London, United Kingdom
⁴⁵University of Manchester, Manchester, United Kingdom
⁴⁶University of Arizona, Tucson, Arizona 85721, USA
⁴⁷Lawrence Berkeley National Laboratory and University of California, Berkeley, California 94720, USA
⁴⁸California State University, Fresno, California 93740, USA
⁴⁹University of California, Riverside, California 92521, USA
⁵⁰Florida State University, Tallahassee, Florida 32306, USA
⁵¹Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA
⁵²University of Illinois at Chicago, Chicago, Illinois 60607, USA
⁵³Northern Illinois University, DeKalb, Illinois 60115, USA
⁵⁴Northwestern University, Evanston, Illinois 60208, USA
⁵⁵Indiana University, Bloomington, Indiana 47405, USA
⁵⁶University of Notre Dame, Notre Dame, Indiana 46556, USA
⁵⁷Purdue University Calumet, Hammond, Indiana 46323, USA
⁵⁸Iowa State University, Ames, Iowa 50011, USA
⁵⁹University of Kansas, Lawrence, Kansas 66045, USA
⁶⁰Kansas State University, Manhattan, Kansas 66506, USA
⁶¹Louisiana Tech University, Ruston, Louisiana 71272, USA
⁶²University of Maryland, College Park, Maryland 20742, USA
⁶³Boston University, Boston, Massachusetts 02215, USA
⁶⁴Northeastern University, Boston, Massachusetts 02115, USA
⁶⁵University of Michigan, Ann Arbor, Michigan 48109, USA
⁶⁶Michigan State University, East Lansing, Michigan 48824, USA
⁶⁷University of Mississippi, University, Mississippi 38677, USA
⁶⁸University of Nebraska, Lincoln, Nebraska 68588, USA
⁶⁹Princeton University, Princeton, New Jersey 08544, USA
⁷⁰State University of New York, Buffalo, New York 14260, USA
⁷¹Columbia University, New York, New York 10027, USA
⁷²University of Rochester, Rochester, New York 14627, USA
⁷³State University of New York, Stony Brook, New York 11794, USA
⁷⁴Brookhaven National Laboratory, Upton, New York 11973, USA
⁷⁵Langston University, Langston, Oklahoma 73050, USA
⁷⁶University of Oklahoma, Norman, Oklahoma 73019, USA
⁷⁷Oklahoma State University, Stillwater, Oklahoma 74078, USA
⁷⁸Brown University, Providence, Rhode Island 02912, USA
⁷⁹University of Texas, Arlington, Texas 76019, USA
⁸⁰Southern Methodist University, Dallas, Texas 75275, USA
⁸¹Rice University, Houston, Texas 77005, USA
⁸²University of Virginia, Charlottesville, Virginia 22901, USA and
⁸³University of Washington, Seattle, Washington 98195, USA

(Dated: November 20, 2007)

We report a search for R -parity violating production and decay of sneutrino particles in the $e\mu$ final state with $1.04 \pm 0.06 \text{ fb}^{-1}$ of data collected with the D0 detector at the Fermilab Tevatron Collider in 2002–2006. Good agreement between the data and the standard model prediction is observed. With no evidence for new physics, we set limits on the R -parity violating couplings λ'_{311} and λ_{312} as a function of sneutrino mass.

Supersymmetry (SUSY) postulates a symmetry between bosonic and fermionic degrees of freedom and predicts the existence of a supersymmetric partner for each standard model (SM) particle. Supersymmetric extensions of the SM provide mechanisms for solving the hierarchy problem and offer the possibility of unification of interactions. An R -parity quantum number is defined as $R = (-1)^{2S+L+3B}$ [1], where B , L and S are, respectively, the baryon and lepton quantum numbers and the spin of the particle, such that SM particles have $R = +1$ and their SUSY partners have $R = -1$. R -parity is often assumed to be conserved, which preserves L and B quantum number invariance and leaves the lightest supersymmetric particle (LSP) stable. However, there is no fully compelling reason for the assumption of R -parity conservation. In general representations of a gauge invariant and renormalizable superpotential, terms of R -parity violation (RPV) can be included as

$$W_{RPV} = \frac{1}{2}\epsilon_{ab}\lambda_{ijk}L_i^aL_j^bE_k + \epsilon_{ab}\lambda'_{ijk}L_i^aQ_j^bD_k + \frac{1}{2}\epsilon_{\alpha\beta\gamma}\lambda''_{ijk}U_i^\alpha D_j^\beta D_k^\gamma + \epsilon_{ab}\mu_iL_i^aH_u^b, \quad (1)$$

where L and Q are the lepton and quark $SU(2)$ doublet superfields, and E , U and D denote the singlet fields. The indices $i, j, k = 1, 2, 3$ refer to fermion generation; $a, b = 1, 2$ are $SU(2)$ isospin indices; and $\alpha, \beta, \gamma = 1, 2, 3$ are $SU(3)$ color indices. The bilinear terms μLH mix the lepton and the Higgs superfields, which could yield neutrino masses and introduce a natural description of neutrino oscillation [2]. The trilinear terms LLE and LQD represent lepton flavor violating interactions, and the UDD terms lead to baryon number violation, where interaction strengths are given, respectively, by the dimensionless Yukawa coupling constants λ , λ' and λ'' .

A single slepton could be produced in hadron collisions by LQD interactions and then decay into SM di-lepton final states via LLE interactions. The observation of a high-mass di-lepton resonance would be evidence of new physics beyond the SM [3]. In this Letter, we report a direct search for resonant production of sneutrinos decaying into an electron and a muon in $p\bar{p}$ collisions at $\sqrt{s}=1.96$ TeV at the Tevatron. The search is performed under the hypothesis that the third-generation sneutrino ($\tilde{\nu}_\tau$) is the LSP and dominant, namely by assuming that all couplings but λ'_{311} and $\lambda_{312} = \lambda_{321}$ are zero. The final state is characterized by an electron and a muon, both of which are well isolated and have high transverse momentum (p_T) which is approximately half of the sneutrino mass. The main background contributions are from $Z/\gamma^* \rightarrow \tau\tau$, WW , $t\bar{t}$, WZ , and ZZ processes that sequentially decay to $e\mu$ final states. High p_T leptons in the signal process allows us to employ high p_T thresholds to suppress the background.

The indirect 2σ upper limit on the product of $\lambda'_{311} \times \lambda_{312}$ from the Sindrum II experiment, reviewed by

Ref. [4], is 2.1×10^{-8} for a degenerated sparticle mass spectrum of $M = 100$ GeV. Under the single coupling dominance assumption, where each coupling at a time is assumed to be non-zero, the indirect 2σ bounds are as

$$\lambda'_{311} \leq 0.12, \quad \lambda_{312} \leq 0.07, \quad M \equiv M_{\tilde{\nu}_\tau} = 100 \text{ GeV}. \quad (2)$$

A direct search for this process has been performed by the CDF Collaboration with Tevatron Run II data [5].

The D0 detector comprises a central tracking system in a 2 T superconducting solenoidal magnet, a liquid-argon/uranium calorimeter, and a muon spectrometer [6]. The tracking system consists of a silicon microstrip tracker (SMT) and a scintillating fiber tracker (CFT) with eight layers mounted on thin coaxial barrels; it provides coverage for charged particles in the pseudorapidity range $|\eta| < 3$, which is defined as $\eta \equiv -\ln[\tan(\frac{\theta}{2})]$ where θ is the polar angle with respect to the proton beam direction. The calorimeter consists of a central section (CC) covering up to $|\eta| \approx 1.1$, and two end caps (EC) extending coverage to $|\eta| \approx 4.2$, each housed in a separate cryostat. Each section consists of an inner electromagnetic (EM) compartment, followed by a hadronic compartment. The EM calorimeter has four longitudinal layers and transverse segmentation of 0.1×0.1 in $\eta - \phi$ space (where ϕ is the azimuthal angle), except in the third layer, where it is 0.05×0.05 . The muon system resides beyond the calorimeter and consists of a layer of tracking detectors and scintillation trigger counters before 1.8 T iron toroidal magnets, followed by two similar layers after the toroids. Luminosity is measured using plastic scintillator arrays located in front of the EC cryostats, covering $2.7 < |\eta| < 4.4$. The data acquisition system consists of a three-level trigger, designed to accommodate the high instantaneous luminosity. For final states containing an electron with p_T above 30 GeV, the trigger efficiency is close to 100%. The data sample used in this analysis was collected between April 2002 and February 2006 and corresponds to an integrated luminosity of $1.04 \pm 0.06 \text{ fb}^{-1}$.

Only electrons in the CC region are considered in this analysis. The electron selection requires (i) an EM cluster with a cone of radius $\Delta R \equiv \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2} = 0.2$ in the central calorimeter, with transverse energy $E_T > 30$ GeV, where E_T is defined as the cluster energy times $\sin\theta$; (ii) at least 90% of the cluster energy be deposited in the EM section of the calorimeter; (iii) the calorimeter isolation variable (I) should be less than 0.15, where $I \equiv \frac{E_{\text{tot}}(0.4) - E_{\text{EM}}(0.2)}{E_{\text{EM}}(0.2)}$, $E_{\text{tot}}(0.4)$ is the total energy in a cone of radius 0.4, and $E_{\text{EM}}(0.2)$ the EM energy in a cone of radius 0.2 around the electron candidate direction; (iv) the transverse and longitudinal shower profiles be consistent with those of electrons; and (v) a track pointing to the EM cluster. To suppress the misidentification of jets as electrons, an electron likelihood discriminant based on the calorimeter variables and additional tracking infor-

mation is defined. To ensure a high efficiency for signal events, we impose the likelihood requirement on electron candidates in the $30 \text{ GeV} < E_T < 100 \text{ GeV}$ region, and not the $E_T \geq 100 \text{ GeV}$ region, where the jet contamination is substantially reduced. The reconstruction efficiencies of electrons are determined from a $Z \rightarrow e^+e^-$ data sample to be $(80 \pm 2)\%$ for $E_T < 100 \text{ GeV}$ and $(86 \pm 2)\%$ for $E_T \geq 100 \text{ GeV}$.

The muon candidate is required to be separated from the electron candidate by $\Delta R > 0.2$ and from any jets by $\Delta R > 0.5$, where jets are reconstructed using an iterative seed-based cone algorithm [7]. In addition, we require (i) that the track p_T be above 25 GeV ; (ii) hits in the muon scintillation counters with time consistent with originating from the proton-antiproton collision; (iii) at least 8 CFT hits along the track; (iv) the E_T sum of the calorimeter cells in the annulus cone of $0.1 < \Delta R < 0.4$ be less than 2.5 GeV , and the transverse momentum sum of all tracks besides the muon track within a cone of radius $\Delta R = 0.5$ be less than 2.5 GeV . The reconstruction efficiency of muons determined from a $Z \rightarrow \mu^+\mu^-$ data sample is $(81 \pm 2)\%$.

To suppress WZ and ZZ background, events having two muon candidates with $p_T > 5 \text{ GeV}$ or two electron candidates with $p_T > 8 \text{ GeV}$ are rejected. In order to suppress the $t\bar{t}$ background, events with missing transverse energy $\cancel{E}_T > 15 \text{ GeV}$ that is not aligned or antialigned in azimuth with the muon ($0.6 < \Delta\phi(\cancel{E}_T, \mu) < 2.5 \text{ rad}$), as well as events with at least one jet with $p_T > 30 \text{ GeV}$ and $|\eta| < 2.5$ are rejected.

The partonic signal events are generated using the COMPHEP program [8] and CTEQ6L [9] parton distribution functions (PDF). The cross section of the process depends on sneutrino mass M and the LQD and LLE coupling constants as [3]

$$\hat{\sigma}_{e\mu} \propto (\lambda'_{311})^2 \times (\lambda_{312})^2 \cdot \frac{1}{|\hat{s} - M^2 + i\Gamma M|^2}, \quad (3)$$

where Γ , the total width of the LSP sneutrino, includes all decay modes ($d\bar{d}$ and $e\mu$), and also depends on the LQD and LLE couplings as

$$\Gamma = [3 \cdot (\lambda'_{311})^2 + 2 \cdot (\lambda_{312})^2] \cdot \frac{M}{16\pi}. \quad (4)$$

A mass-dependent K -factor is applied to include next-to-leading order QCD corrections [10]. The partonic signal events are processed through PYTHIA [11] to include parton showering, hadronization and particle decays. The influence of the PDF uncertainty on the cross section times acceptance is $6.2\% - 8.6\%$ depending on the sneutrino mass, estimated from the CTEQ6M error functions. The cross section uncertainty from the choice of renormalization scale and factorization scale is about 4% . Standard model background processes are generated with PYTHIA and CTEQ6L1. The contribution of Drell-Yan Z/γ^* processes is normalized using the NNLO cross section [12]. The contributions of WW , WZ and $t\bar{t}$ processes are normalized with NLO cross sections [13, 14].

TABLE I: The numbers of selected events in data and different estimated background contributions.

Process	Events
$Z/\gamma^* \rightarrow \tau\tau$	42.9 ± 4.2
WW	13.7 ± 1.5
$t\bar{t}$	1.4 ± 0.3
WZ	1.2 ± 0.2
Total background	59.2 ± 5.3
Data	68

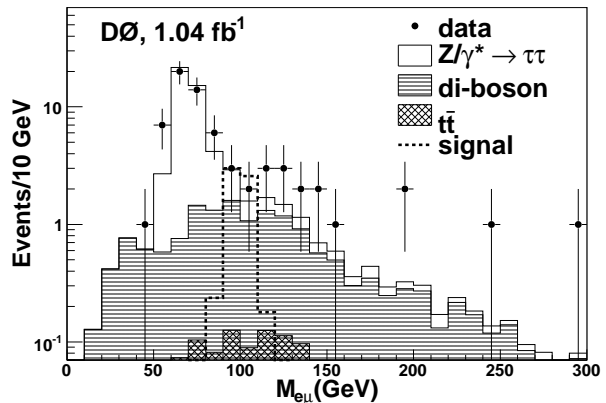


FIG. 1: Invariant mass of the electron-muon system. The di-boson contribution includes the WW and WZ processes. The dashed line indicates the signal Monte Carlo simulation of sneutrino with mass of 100 GeV and $\sigma \times BR$ of 0.057 pb .

All signal and background events are processed with a detailed GEANT-based D0 detector simulation [15], and are corrected for trigger effects and the differences in the reconstruction efficiencies compared to those in data. The background from misidentification of photons or jets as leptons, such as $W\gamma$ and W +jet and QCD di-jet events, is estimated from data and is found to be negligible given our stringent event selection criteria.

The number of selected events in data and the estimated background contributions are summarized in Table I. The ZZ contribution is found to be negligible after the event selection and is not listed. There are 68 candidates found in the data. The expectation from the SM processes is 59.2 ± 5.3 events, where the uncertainty includes the statistical uncertainty and uncertainties from the integrated luminosity (6%), reconstruction and trigger efficiencies (3.1%), and background cross sections (Z/γ^* (3.5%), $t\bar{t}$ (14.7%), and di-boson production ($5.6-6.6\%$)). The kinematic variables of the final state are well described by the sum of the SM background contributions. The distribution of the electron and muon invariant mass ($M_{e\mu}$) is shown in Fig. 1.

Using the $M_{e\mu}$ distributions, we calculate an upper limit on $\sigma \times BR$ for the process $p\bar{p} \rightarrow \tilde{\nu}_\tau + X \rightarrow e\mu + X$ with a modified frequentist (CL_s) method [16], under the assumption that the total width is much narrower than

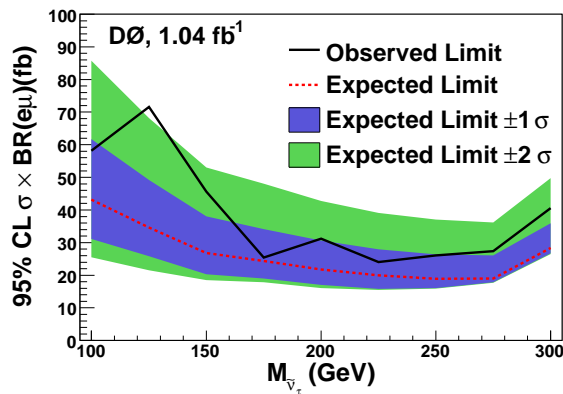


FIG. 2: The observed and expected upper limits on $\sigma \times BR$ at 95% CL for the process $p\bar{p} \rightarrow \tilde{\nu}_\tau + X \rightarrow e\mu + X$ as a function of the sneutrino mass, assuming that the sneutrino total width is much narrower than our detector resolution (color online).

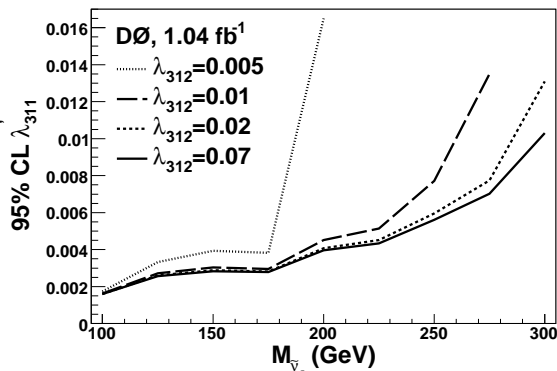


FIG. 3: The observed upper limits on λ'_{311} at 95% CL for four fixed values of λ_{312} as a function of the sneutrino mass.

the detector resolution. The upper limits as a function of the sneutrino mass are shown in Fig. 2. We fix one of the coupling constants and set the upper limit on the other for different sneutrino masses. Shown in Fig. 3 are the observed upper limits on λ'_{311} for four assumed values of λ_{312} . For a sneutrino with mass of 100 GeV, $\lambda'_{311} > 1.6 \times 10^{-3}$ is excluded at 95% CL when $\lambda_{312} = 0.01$.

In summary, we have studied the production of high p_T electron-muon pair final states with about 1 fb^{-1} of D0 data. We select 68 events, while the SM expectation is 59.2 ± 5.3 events. The distributions of kinematic variables are in good agreement with the SM predictions. We set limits on the parameters of a particular supersymmetric model which predicts an enhancement of the high p_T electron-muon final state via R -parity violating production and decay of sneutrino particles. These are the most stringent direct limits to date.

We thank the staffs at Fermilab and collaborating institutions, and acknowledge support from the DOE and NSF (USA); CEA and CNRS/IN2P3 (France); FASI, Rosatom and RFBR (Russia); CAPES, CNPq, FAPERJ, FAPESP and FUNDUNESP (Brazil); DAE and DST (India); Colciencias (Colombia); CONACyT (Mexico); KRF and KOSEF (Korea); CONICET and UBACyT (Argentina); FOM (The Netherlands); Science and Technology Facilities Council (United Kingdom); MSMT and GACR (Czech Republic); CRC Program, CFI, NSERC and WestGrid Project (Canada); BMBF and DFG (Germany); SFI (Ireland); The Swedish Research Council (Sweden); CAS and CNSF (China); Alexander von Humboldt Foundation; and the Marie Curie Program.

- [a] Visitor from Augustana College, Sioux Falls, SD, USA.
- [b] Visitor from The University of Liverpool, Liverpool, UK.
- [c] Visitor from ICN-UNAM, Mexico City, Mexico.
- [d] Visitor from II. Physikalisches Institut, Georg-August-University Göttingen, Germany.
- [e] Visitor from Helsinki Institute of Physics, Helsinki, Finland.
- [f] Visitor from Universität Zürich, Zürich, Switzerland.
- [‡] Deceased.
- [1] G.R. Farrar and P. Fayet, Phys. Lett. B **76**, 575 (1978).
- [2] J.C. Romao *et al.*, Phys. Rev. D **61**, 071703 (2000); Phys. Rev. D **62**, 113008 (2000).
- [3] Y.B. Sun *et al.*, Commun. Theor. Phys. **44**, 107 (2005). L.L. Yang *et al.*, Phys. Rev. D **72**, 074026 (2005). H.K. Dreiner *et al.*, Phys. Rev. D **75**, 035003 (2007). Y.Q. Chen, T. Han and Z.G. Si JHEP **0705**, 068 (2007).
- [4] R. Barbier *et al.*, Phys. Rept. **420**, 1 (2005).
- [5] A. Abulencia *et al.*, (CDF Collaboration), Phys. Rev. Lett. **96**, 211802 (2006).
- [6] V.M. Abazov *et al.*, Nucl. Instrum. Meth. A **565**, 463

- (2006).
- [7] G.C. Blazey *et al.*, in *Proceedings of the Workshop "QCD and Weak Boson Physics in Run II,"* edited by U. Baur, R.K. Ellis and D. Zeppenfeld, Fermilab-Pub-00/297 (2000), arXiv:hep-ex/0005012.
- [8] A. Pukhov *et al.*, Preprint INP MSU 98-41/542 (arXiv:hep-ph/9908288).
- [9] J. Pumplin *et al.*, JHEP **0207**, 012 (2002).
- [10] S.M. Wang *et al.*, Phys. Rev. D **74**, 057902 (2006) and S.M. Wang *et al.*, arXiv:0706.3079v1 [hep-ph], accepted by Chinese Phys. Lett.
- [11] T. Sjöstrand *et al.*, Comput. Phys. Commun. **135**, 238 (2001). We use version 6.323, documented in arXiv:hep-ph/0308153.
- [12] R. Hamberg, W.L. van Neerven, and T. Matsuura, Nucl. Phys. B **359** 343 (1991) [Erratum-ibid. B **644** 403 (2002)].
- [13] J.M. Campbell and R.K. Ellis, Phys. Rev. D **60**, 113006 (1999).
- [14] M. Cacciari *et al.*, JHEP **0404**, 068 (2004).
- [15] R. Brun and F. Carminati, CERN Program Library Long Writeup, Report No. W5013, 1993.

- [16] A.L. Read, J. Phys. G **28**, 2693 (2002).